High School Earth Science Standards and Learning Activities

SCIENTIFIC INVESTIGATION AND INQUIRY

ES.1. Broad Concept: Scientific progress is made by asking relevant questions and conducting careful investigations. As a basis for understanding this concept, and to address the content in this grade, students should develop their own questions and perform investigations.

Students:

1. Know the elements of scientific methodology (identification of a problem, hypothesis formulation and prediction, performance of experimental tests, analysis of data, falsification, developing conclusions, reporting results) and be able to use a sequence of those elements to solve a problem or test a hypothesis. Also, understand the limitations of any single scientific method (sequence of elements) in solving problems.
2. Know that scientists cannot always control all conditions to obtain evidence, and when they are unable to do so for ethical or practical reasons, they try to observe as wide a range of natural occurrences as possible so as to be able to discern patterns.
3. Recognize the cumulative nature of scientific evidence.
4. Recognize the use and limitations of models and theories as scientific representations of reality.
5. Distinguish between a conjecture (guess), a hypothesis and a theory as these terms are used in science.
6. Plan and conduct scientific investigations to explore new phenomena, to check on previous results, to verify or falsify the prediction of a theory, and to use a crucial experiment to discriminate between competing theories.
7. Use hypotheses to choose what data to pay attention to and what additional data to seek, and to guide the interpretation of the data.
8. Identify and communicate the sources of error (random and systematic error) inherent in an experiment.
9. Identify discrepant results and identify possible sources of error or uncontrolled conditions.
10. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data. (The focus is on manual graphing, interpreting graphs, and mastery of metric measurements and units, with supplementary use of computers and electronic data gathering when appropriate.)
11. Formulate and revise explanations using logic and evidence.
12. Analyze situations and solve problems that require combining concepts from more than one topic area of science and applying these concepts.
13. Apply mathematical relationships involving proportionalities, linear relations, quadratic equations, simple trigonometric relationships, exponential growth and decay laws, and logarithmic relationships to scientific situations.
14. Recognize the implications of statistical variability in experiments, and explain the need for controls in experiments.
15. Observe natural phenomena, and analyze their location, sequence, or time intervals (e.g., relative ages of rocks, locations of planets over time, and succession of species in an ecosystem).
16. Read a topographic map and a geologic map for information provided on the maps.

SCIENTIFIC INVESTIGATION AND INQUIRY (CONTINUED)

17. Construct and interpret a simple scale map and topographic cross-section.

18. Describe the contributions of key scientists throughout history, including Claudius Ptolemy, Nicholas Copernicus, Johannes Kepler, Tycho Brahe, Galileo Galilei, Nicholas Steno, Sir Charles Lyell, James Hutton, Henrietta Leavitt, Alfred Wegener, and Edwin Powell Hubble.

Examples

Students conduct a field study of the degradation of local monuments and research any efforts being taken by the government to preserve and protect them (ES.1.1).

Students compare and contrast lines of evidence for theories of dinosaur extinction (ES.1.3).

Students compare models and topographic maps to images/pictures of real mountains.

Students discuss the limitations of a model in terms of real-time changes to mountains and elevation due to weathering (ES.1.4).

Students examine the fossil evidence for early human evolution (e.g., www.pbs.org/wgbh/evolution/humans/riddle/index.html). They offer varying options for interpreting that evidence and qualify their opinions as hypothesis or conjecture (ES.1.5).

Students investigate how to assist a track team that travels around North America adjust to altitudes different from the place they usually train, and then they explain why these adjustments are necessary (ES.1.6).

Students hypothesize about weather pattern effects on dissolved oxygen concentration in local bodies of water. Students then determine their protocol for selecting data for conducting research and determine how to collect real-time data locally (ES.1.7 and ES.1.8).

Students use dissolved oxygen probes to test water samples from local ponds, streams, or other bodies of water to determine how the environment, seasons, or the location of a body of water affects dissolved oxygen concentrations (ES.1.10).

Students study the ecological impact of the construction of the Wilson Bridge on the local ecosystem (ES.1.12).

Given earthquake data such as location and the time to reach select cities, students calculate the P and S wave magnitudes of an earthquake and its epicenter (ES.1.13).

Students create mini-biography posters for key scientists that include their discoveries, years of completion, and countries of origin. After hanging the posters, students complete a gallery walk and discuss as a group how each scientist advanced or changed the scientific thinking of their time and the applicability of each discovery today (ES.1.18).

THE UNIVERSE

ES.2. Broad Concept: Galaxies are made of billions of stars and form most of the visible mass of the universe. As a basis for understanding this concept,

Students:

1. Recognize that the universe contains many billions of galaxies, and each galaxy contains many billions of stars.
2. Describe various instrumentation used to study deep space and the solar system (e.g., telescopes that record in various parts of the electromagnetic spectrum, including visible, infrared, and radio, refracting or reflecting telescopes, and spectrophotometer).
3. Describe Hubble's law, and understand the big bang theory and the evidence that supports it (microwave background radiation, relativistic Doppler effect).
4. Explain the basics of the fusion processes that are the source of energy of stars.
5. Explain that the mass of a star and the balance between collapse and fusion determine the color, brightness, lifetime, and evolution of a star.
6. Analyze the life histories of stars and different types of stars found on the Hertzsprung-Russell diagram, including the three outcomes of stellar evolution based on mass (black hole, neutron star, white dwarf).
7. Describe how elements with an atomic number greater than helium have been formed by nuclear fusion processes in stars, supernova explosions, or exposure to cosmic rays.
8. Explain that the redshift from distant galaxies and the cosmic microwave background radiation provide evidence for the big bang model that the universe has been expanding for 13 to 14 billion years.
9. Construct a model and explain the relationships among planetary systems, stars, multiple-star systems, star clusters, galaxies, and galactic groups in the universe.

Examples

Students complete an organization chart for each type of instrumentation. They create an advertisement to promote one type of instrumentation, including such information as lens type/construction, use, examples of images "captured" by instrument, size of the instrument, its location (mountain top, satellite, probe, etc.), history, and cost (ES.2.2).

Students use a marker on an empty balloon to note galaxies. They draw wavy lines between them to simulate radiation travel and lines between stars, using superglue to simulate the effects of gravity. As the balloon expands, they observe the marks grow in size and move away from one another, simulating the travel of galaxies in an expanding universe. They also observe how the superglue "warps" the balloon (ES.2.3 and ES.2.9).

Students calculate the relationship between the mass of the sun and its color, brightness, and how close it is to collapse (ES.2.5).

Given star data on luminosity and temperature, students plot the data on a Hertzsprung-Russell Diagram and use size and color to classify the star (ES.2.6).

Students use redshift data from various Web sites to determine the distance of remote galaxies from earth (WMAP satellite information is available at map.gsfc.nasa.gov/m_mm.html) (ES.2.8).

THE SOLAR SYSTEM

ES.3. Broad Concept: Our solar system is composed of a star, planets, moons, asteroids, comets, and residual material left from the evolution of the solar system over time. The sun is one of billions of stars residing in one of billions of galaxies in a universe that has been changing and evolving over vast amounts of time. As a basis for understanding this concept,

Students:

1. Describe the location of the solar system in an outer edge of the disc-shaped Milky Way galaxy, which spans 100,000 light-years.
2. Compare and contrast the differences in size, temperature, and age of our sun and other stars.
3. Understand and describe the nebular theory concerning the formation of solar systems, including the roles of planetesimals and protoplanets.
4. Observe and describe the characteristics and motions of the various kinds of objects in our solar system, including planets, satellites, comets, and asteroids, and the influence of gravity and inertia on these motions.
5. Explain how Kepler's laws predict the orbits of the planets.

Examples *Students view a simplified animation of the circular motion of planets around the sun. They distinguish the simulated circular orbits from the planets' actual elliptical orbits and adjust the positions of planets in the interactive animation to demonstrate varying effects of gravity on their orbits (information is available at www.arachnoid.com/gravitation/index.html) (ES.3.4).*

Students view an animation on Kepler's Law and apply Kepler's calculations to selected planets to determine their orbits (information is available at csep10.phys.utk.edu/astr161/lect/history/kepler.html) (ES.3.5).

THE EARTH SYSTEM

ES.4. Broad Concept: Interactions among the solid Earth, hydrosphere, and atmosphere have resulted in ongoing evolution of the earth system over geologic time. As a basis for understanding this concept,

Students:

1. Examine and describe the structure, composition, and function of Earth's atmosphere, including the role of living organisms in the cycling of atmospheric gases.
2. Investigate and describe the composition of the Earth's atmosphere as it has evolved over geologic time (outgassing, origin of atmospheric oxygen, variations in carbon dioxide concentration).
3. Describe the main agents of erosion: water, waves, wind, ice, plants, and gravity.
4. Explain the effects on climate of latitude, elevation, and topography, as well as proximity to large bodies of water and cold or warm ocean currents.
5. Explain the possible mechanisms and effects of atmospheric changes brought on by things such as acid rain, smoke, volcanic dust, greenhouse gases, and ozone depletion.
6. Determine the origins, life cycles, behavior, and prediction of weather systems.
7. Investigate and identify the causes and effects of severe weather.

THE EARTH SYSTEM (CONTINUED)	
8.	Explain special properties of water (e.g., high specific and latent heats) and the influence of large bodies of water and the water cycle on heat transport and, therefore, weather and climate.
9.	Describe the development and dynamics of climatic changes over time corresponding to changes in the Earth's geography (plate tectonics/continental drift), orbital parameters (the Milankovitch cycles), and atmospheric composition.
10.	Describe the nitrogen and carbon cycles and their roles in the improvement of soils for agriculture.
11.	Explain that the oceans store carbon dioxide mostly as dissolved HCO_{3-} and $CaCO_3$ as precipitate or biogenic carbonate deposits.
12.	Use weather maps and other tools to forecast weather conditions.
13.	Use computer models to predict the effects of increasing greenhouse gases on climate for the planet as a whole and for specific regions.
14.	Read and interpret space weather data (solar flares, geomagnetic storms, solar wind).
Examples	*Students research the engineering necessary to make such objects as airplanes, weather balloons, space shuttles, and satellites travel-ready for a certain layer of Earth's atmosphere, including considerations of temperature, air pressure, ionization and radiation effects, etc. (ES.4.1).* *Students graph the change in CO_2 concentration of Earth's atmosphere over time (ES.4.2).* *Students choose countries from different regions of the globe. They compare the vegetation, animal life, and economic trade from each region, and they evaluate how differences in climates and proximity to waters affect those resources (ES.4.4).* *Students research the "Kyoto Protocol." They evaluate the opinions, hypotheses, evidence, and range of data used to argue for or against the usefulness of the protocol (ES.4.5).* *Students use satellite images to complete an information pamphlet on a specific weather system that includes its origins, life cycle, and behavior. They include information on storm preparedness information is available at www.weather.com or www.noaa.gov) (ES.4.6).* *Students track, by plotting latitude and longitude, the formation of tropical lows as they build to hurricane status and explain the contributing factors that lead to intensification. When possible, students use real-time data for current hurricane season in the Atlantic Ocean (information is available at www.weather.com, www.noaa.gov, or www.nhc.noaa.gov) (ES.4.8).* *Students determine the carbon, nitrogen, and oxygen needed to maintain and improve the yields of different local agricultural crops (ES.4.10).* *Students examine sand samples and shell samples for the presence of H_2CO_3 and $CaCO_3$ presence using white vinegar. (The presence of both carbonates will cause a reaction of bubbling.) Students explain why the oceans are a great storehouse for carbon-based molecules (ES.4.11).*

THE HYDROLOGIC CYCLE

ES.5. Broad Concept: Water is continually being recycled by the hydrologic cycle through the watersheds, oceans, and the atmosphere by processes such as evaporation, condensation, precipitation runoff, and infiltration. As a basis for understanding this concept,

Students:

1. Explain how water flows into and through a watershed (e.g., properly use terms precipitation, aquifers, wells, porosity, permeability, water table, capillary water, and runoff).
2. Describe the processes of the hydrologic cycle, including evaporation, condensation, precipitation, surface runoff, and groundwater percolation, infiltration, and transpiration.
3. Identify and explain the mechanisms that cause and modify the production of tides, such as the gravitational attraction of the moon, the sun, and coastal topography.

Examples

Students test the permeability of a variety of soil samples by making their own varied compositions with rock, gravel, sand, dirt, clay, and water. They compare their compositions with local soil samples. (Links can be drawn to local events, such as the post-drought season in Texas) (ES.5.1).

Students create a terrarium to observe the hydrologic cycle (ES.5.2).

Students chart tidal cycles (high and low tides) for the lower Potomac for 60 days. Students use the same chart to record the lunar cycle and compare the phases of the moon to the maximum high and minimum low marks of the tide. (Tide information is at tidesandcurrents.noaa.gov; lunar cycle information is at www.space.com/scienceastronomy/solarsystem/moon-ez.html) (ES.5.3).

Students simulate tidal interactions by placing metal filings on the surface of a container of water and "orbiting" a magnet around the container that attracts the metal filings in a manner that simulates ebb and flow (ES.5.3).

THE ROCK CYCLE

ES.6. Broad Concept: Rocks and minerals are continually being modified within the rock cycle. As a basis for understanding this concept,

Students:

1. Differentiate among the processes of weathering, erosion, transportation of materials, deposition, and soil formation.
2. Illustrate the various processes and rock types that are involved in the rock cycle, and describe how the total amount of material stays the same throughout formation, weathering, sedimentation, and reformation.
3. Explain the absolute and relative dating methods used to measure geologic time.
4. Recognize and explain geologic evidence, including fossils and radioactive dating, that indicates the age of the Earth.
5. Trace the evolution of the solid Earth in terms of the major geologic eras.

THE ROCK CYCLE (CONTINUED)

Examples *Students create a stream table out of a container of rocks, clay, and dirt. They excavate paths for the stream to build a river system. They observe the changes over time due to simulated precipitation (ES.6.1).*

Students use the rock cycle to determine the best type of rock to use to construct a town monument (ES.6.2).

Students evaluate the effectiveness of carbon-14 dating to help identify human ancestors (information is available at www.c14dating.com/index.html) (ES.6.3).

Students examine fossil structure, superposition of rocks, and DNA comparison that marks different eras of Earth's history (information is available at www.ucmp.berkeley.edu/education/explotime.html) (ES.6.4 and ES.6.5).

PLATE TECTONICS

ES.7. Broad Concept: Plate tectonics operating over geologic time has altered the features of land, sea, and mountains on the Earth's surface. As the basis for understanding this concept,

Students:

1. Explain the work of Alfred Wegener, including reintroduction of the idea of moving continents, and the skepticism with which his theories were first received and why.
2. Analyze the evidence that supports the hypothesis of movement of the plates (from paleomagnetism, paleontology, paleoclimate, and the continuity of geological structure and stratigraphy across ocean basins).
3. Trace the development of a lithospheric plate from its growing margin at a divergent boundary (mid-ocean ridge) to its destructive margin at a convergent boundary (subduction zone).
4. Explain the relationship between convection currents and the motion of the lithospheric plates.
5. Explain why, how, and where earthquakes occur, how they are located and measured, and the ways that they can cause damage (directly by shaking and secondarily by fire, tsunami, landsliding, or liquefaction).
6. Observe and explain how rivers and streams are dynamic systems that erode and transport sediment, change their course, and flood their banks in natural and recurring patterns.

Examples *Students create a plate tectonics picture book for students in lower-level grades (ES.7.2).*

Students create and use a mathematical model for seafloor spreading to determine the rate of seafloor spreading per year (ES.7.3).

Students map earthquake "zones" and create safety "readiness" pamphlets or posters for schools in these zones (ES.7.5).

Students graph the flooding patterns of the Mississippi over the past 100 years, evaluate any positive and negative effects, and study different ways of regulating, reducing, or eliminating the likelihood of flooding (ES.7.6).